

# PACIFIC SOUTHWEST Forest and Range Experiment Station

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## FROND DEVELOPMENT AND STEM GROWTH OF TREEFERN IN HAWAII

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Treefern (*Cibotium* spp.) is a major component of rain forests in Hawaii. Often forming a dense canopy, the species is highly desirable esthetically and for watershed protection. And it has found a variety of commercial uses. In some places treefern creates severe competition for planted trees in reforestation sites. This competition is particularly noticeable on recently cleared sites where treefern regrowth is rapid (fig. 1). Carpenter<sup>1</sup> and Null and Carpenter<sup>2</sup> reported that chemical control of frond growth in treefern is not easily achieved.

The stem of treeferns consists of a closely packed mass of aerial roots that has considerable commercial value as a growth medium for ornamental plants and as an art medium for decorative carvings. The island of Hawaii has the only commercially available treefern and supports a small industry engaged in harvesting and remanufacturing the stem material.

The most common treefern—hapu'u-pulu (*C. splendens* [Gaud.] Krajina, syn. *C. chamissoi*)—produces a densely packed fiber that is excellent for chips, chunks, fiber, and carvings. The largest treefern—hapu'u-ii (*C. chamissoi* Kuulf., syn. *C. menziesii*)—has a more loosely packed stem material that is preferred for sawed plant-support poles because it is lighter to ship and is the best rooting medium in its natural form. A third species that we studied—hapu'u (*C. glaucum* [J. E. Smith] Hook. and Arn.)—is not common. It has a smaller diameter stem than the other two species. But the stem is densely packed material that is preferred for carving.

In the past, treefern has been used for a variety of other purposes. The silky, fawn-colored wool (pulu) that clothes the frond stem base served as a filler for pillows and mattresses, as a dressing for wounds, and a material for embalming. In the mid-1800's, pulu amounting to several hundred thousand pounds a year was exported to the United States mainland.<sup>3,4</sup> A treefern often produces from 50 to 70 pounds of

**Abstract:** In a study of the growth habits of hapu'u-pulu treefern (*Cibotium splendens*) on the island of Hawaii, frond life averaged 21 months and frond length averaged 10 feet. Most new fronds emerged in late winter. Average frond life varied inversely with bole diameter. Average frond length varied directly with bole diameter. Fronds averaged five per plant regardless of elevation or season. Annual growth of bole diameter averaged less than 0.1 inch and that of bole height less than 2 inches.

Oxford: 173.5 *Cibotium splendens* (969):161.4.

Retrieval Terms: *Cibotium splendens*; growth habits; leaf development; Hawaii.



Figure 1—*Hapu'u-pulu* (*Cibotium splendens*), growing in the native ohia rain forest, can reach heights of more than 40 feet and diameters greater than 4 feet.

nearly pure starch.<sup>4</sup> The early Hawaiians, in times of famine, cooked the starch for food. In the 1920's, a short-lived starch industry used the treefern core to produce laundry and cooking starch.

Information is needed about the growth habits of treefern as a basis for the scientific management, protection, and perpetuation of the species, including control where necessary. In 1966, William S. Null, formerly of the Pacific Southwest Forest and Range Experiment Station's staff in Hawaii, conceived a study of frond development and stem growth of three treefern species: hapu'u-pulu, hapu'u-ii, and hapu'u. We report observations and measurements from field plots that he established.

#### IDENTIFICATION OF TREEFERN

The three species of treefern we studied can be readily identified by using the following key by Joe.<sup>5</sup>

1. Stipe and rachis with stiff purplish-black hairs; under-surface of segment often with minute tufts of matted hairs: hapu'u-ii (*C. chamissoi*).

1. Stipe and rachis with only yellowish to dark brown hairs; undersurface of segment never with hairs in minute tufts.

2. One or both segments at base of pinnule eared and deflexed: hapu'u (*C. glaucum*).

2. None of the segments at base of pinnule eared.

3. Undersurface of segment covered with cob-web-like hairs: hapu'u-pulu (*C. splendens*).

#### STUDY SITES AND METHODS

Treefern plants were observed and measured at several sites on the Waiakea-Olaa Reforestation Area on the northeast slope of Mauna Loa, on the island of Hawaii. The treeferns were growing in the undisturbed native rain forest type next to the Stainback Highway. Three weather stations near the study sites showed an annual rainfall, for the 3-year study period, of 194 inches at 1,800-foot elevation, 184 inches at 3,000-foot elevation, and 140 inches at 4,000-foot elevation. The maximum-minimum temperatures during the measurement period were 80° and 54°F. at 1,800 ft.; 77° and 53°F. at 3,000 ft.; and 71° and 45°F. at 4,000 feet.<sup>6</sup>

Treefern plants were selected to represent various sizes and species at elevations from 1,000 feet to 5,000 feet. Four hapu'u-pulu were selected at each sample area. In addition, one hapu'u-ii or hapu'u was selected to make five sample trees per sample site. (The sample area at 4,000 feet had all five treefern of hapu'u-pulu.) Base diameters ranged from 5.3 to 14.3 inches. Bole lengths ranged from 1.3 to 7.6 feet, and total heights ranged from 5.7 to 18.6 feet.

Each treefern was numbered and tagged. Each live frond was tagged and the frond stage recorded. Dead fronds were removed and emerging fiddleheads were identified and recorded. Once elongation of a fiddle head began it was tagged. The base diameter of the bole (diameter 1-foot above the ground) and the length of the bole were measured at the beginning of the study (July 1966) and 3 years later. The total plant height (distance from the ground to highest frond tip), the length of the longest frond, and the length of the shortest frond were also measured at the beginning of the study and 3 years later.

Plots were inspected each month and each frond classified as to stage of development according to this code: (1) an emergent fiddlehead; (2) fiddlehead elongating but without pinnae (side branches); (3) fiddlehead elongating with pinnae appressed; (4)

fiddlehead and pinnae elongating; (5) fiddlehead and pinnae fully extended but succulent; (6) frond mature and healthy appearing; (7) mature frond but becoming brown; (8) frond dead but upright; (9) frond dead and fallen.

## RESULTS

Generally, we found that treeferns growing in the open were smaller, had shorter fronds and smaller boles than the treeferns growing under a forest canopy.

Fronds emerged and grew during most of the year. Sixty percent of the new fiddleheads emerged between January and mid-March, when frond mortality was consistently high (table 1). As a result, the number of fronds per treefern was fairly uniform throughout the year. New fronds emerged slightly earlier at the lower elevations than at the higher elevations (table 2). There were on the average 4.3 mature fronds per treefern (table 3), and an over-all average (all stages of frond development) of five per plant.

Fronds of hapu'u-pulu had an average life of 21 months. The average frond life ranged from 19 months at 1,000 feet elevation to 24 months at 5,000 feet elevation. However, frond life varied so widely within each elevation class that elevation differences were not statistically significant. Our sample data from 21 hapu'u-pulu plants showed that the larger the bole diameter (X), the shorter the frond life in months (Y) ( $Y = 36.85 - 2.08X$  [ $r = 0.76$ ]).

Mature fronds averaged 10 feet long, ranging from 4 to 15 feet. On the average the longest and the

Table 2—New fronds, observed on hapu'u-pulu treefern, by elevation and month, Waiakea-Olaa Reforestation area, island of Hawaii, 1966-1969

| Month     | Elevation (feet) |       |       |       |       | Total |
|-----------|------------------|-------|-------|-------|-------|-------|
|           | 1,000            | 2,000 | 3,000 | 4,000 | 5,000 |       |
|           | Number           |       |       |       |       |       |
| January   | 9                | 2     | 3     | 3     | —     | 17    |
| February  | 12               | 9     | 14    | 8     | —     | 43    |
| March     | 12               | 17    | 31    | 34    | 19    | 113   |
| April     | 2                | 9     | 10    | 4     | 28    | 53    |
| May       | 2                | —     | —     | —     | 20    | 22    |
| June      | 2                | 1     | —     | —     | 1     | 4     |
| July      | 2                | 1     | —     | 3     | —     | 6     |
| August    | 3                | —     | 1     | —     | 1     | 5     |
| September | 1                | —     | —     | 1     | —     | 2     |
| October   | 1                | —     | —     | 1     | —     | 2     |
| November  | —                | —     | —     | —     | —     | 0     |
| December  | —                | —     | —     | —     | —     | 0     |
| Totals    | 46               | 39    | 59    | 54    | 69    | 267   |

Table 3—Mature fronds observed on hapu'u-pulu treefern by elevation and month, Waiakea-Olaa Reforestation area, island of Hawaii, 1966-1969

| Month     | Elevation (feet) |       |       |       |       | Total |
|-----------|------------------|-------|-------|-------|-------|-------|
|           | 1,000            | 2,000 | 3,000 | 4,000 | 5,000 |       |
|           | Number           |       |       |       |       |       |
| January   | 76               | 53    | 53    | 58    | 63    | 303   |
| February  | 76               | 48    | 51    | 53    | 62    | 290   |
| March     | 78               | 48    | 51    | 50    | 59    | 286   |
| April     | 81               | 48    | 51    | 23    | 52    | 255   |
| May       | 93               | 69    | 71    | 34    | 50    | 317   |
| June      | 86               | 63    | 75    | 61    | 49    | 334   |
| July      | 86               | 57    | 74    | 71    | 76    | 364   |
| August    | 84               | 54    | 69    | 68    | 76    | 351   |
| September | 86               | 55    | 68    | 70    | 73    | 352   |
| October   | 88               | 56    | 68    | 68    | 72    | 352   |
| November  | 84               | 56    | 60    | 61    | 68    | 329   |
| December  | 78               | 56    | 59    | 62    | 67    | 322   |
| Totals    | 996              | 663   | 750   | 679   | 767   | 3,855 |

Table 1—Dead fronds observed on hapu'u-pulu treefern, by elevation and month, Waiakea-Olaa Reforestation area, island of Hawaii, 1966-1969

| Month     | Elevation (feet) |       |       |       |       | Total |
|-----------|------------------|-------|-------|-------|-------|-------|
|           | 1,000            | 2,000 | 3,000 | 4,000 | 5,000 |       |
|           | Number           |       |       |       |       |       |
| January   | 2                | 3     | 6     | 2     | 4     | 17    |
| February  | 2                | 6     | 5     | 5     | 2     | 20    |
| March     | 2                | —     | 4     | 1     | 4     | 11    |
| April     | 4                | 3     | 7     | 2     | 10    | 26    |
| May       | 1                | 4     | 4     | 3     | —     | 12    |
| June      | 2                | 3     | 2     | —     | 2     | 9     |
| July      | 1                | 3     | 2     | 3     | 4     | 13    |
| August    | 1                | 1     | 1     | 4     | 4     | 11    |
| September | —                | —     | 1     | 1     | —     | 2     |
| October   | —                | —     | 1     | —     | —     | 1     |
| November  | 8                | 2     | 8     | 5     | 3     | 26    |
| December  | 2                | —     | 1     | 1     | 1     | 5     |
| Totals    | 25               | 25    | 42    | 27    | 34    | 153   |

shortest mature fronds on an individual treefern differed by about 1.4 feet. Our data showed that frond length in feet (Y) and bole diameter in inches (X) were positively correlated ( $Y = 5.62 + 0.49X$  [ $r = 0.61$ ]).

Growth of the hapu'u-pulu treefern bole is slow. During the 3-year measurement period, annual base diameter growth averaged less than 0.1 inch, with a range of 0 to 0.2 inch per year. Bole height growth averaged less than 2 inches per year, with a range of 0 to 8 inches per year. These measured height growth rates are appreciably less than the 4.35 inches per year reported by Ripperton.<sup>7</sup> Total treefern height

(bole and fronds) averaged 11 feet, with a range of 6 to 19.6 feet.

Only three plants of hapu'u-ii were observed. They had an average frond life of 14 months. This life span ranged from 13 months at 1,000 feet elevation to 15 months at the 3,000 foot elevation point.

Frond development in hapu'u-ii was similar to that of hapu'u-pulu—most of the new fronds developed from January to May. The number of mature fronds averaged 3.6 per treefern, and over-all (all stages of frond development) 4.2 per treefern.

The limited data for hapu'u-ii suggest that it grew slower—both in base diameter and in bole length—than hapu'u-pulu. Our sample averaged 10 feet in height, and bole length averaged about 3 feet. Hapu'u-ii do, however, achieve much larger size, sometimes reaching heights of 40 feet and diameters of greater than 4 feet. Frond length averaged 9 feet. The longest frond exceeded 11 feet, and the shortest frond was about 6 feet. The longest and shortest frond on an individual treefern differed only by about 1 foot.

Only one hapu'u was measured—at 5,000 feet elevation. New fronds there developed in March and April at the same time the hapu'u-pulu developed; the average was six mature fronds per treefern, and an over-all average of eight fronds per treefern. Life of fronds averaged 22.7 months. There was no measurable diameter or height growth over the 3-year period. Frond height averaged slightly more than 9 feet, ranging from 8 to 12 feet.

Our sample data, while limited to only 21 plants of hapu'u-pulu, showed these correlations: a positive correlation between frond length and bole diameter, a positive correlation between number of fronds and bole diameter, and a negative correlation between length of frond life and bole diameter.

We found that hapu'u-pulu grew at a much slower rate than reported earlier.<sup>7</sup> Our data suggest that the

larger treeferns scattered through the native rain forest are old. Forest protection and management activities should recognize that if we hope to maintain this resource, much longer rotation cycles will be needed than previously thought. For example, Nelson and Hornibrook<sup>8</sup> defined a merchantable treefern as one at least 8 inches in base diameter. To reach this size, a hapu'u-pulu tree would require 80 years if it grew 0.1 inch per year in diameter. General observations suggest that treeferns grow at a much faster rate. Because growth data are scarce, the productivity of treeferns merits further study.

## NOTES

<sup>1</sup>Carpenter, Stanley B. *Herbicides for site preparation... broadcast spray by mist blower tested against understory in Hawaii rainforest*. U.S. Forest Serv. Res. Note PSW-115. Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif. 8 p., illus. 1966.

<sup>2</sup>Null, W. S., and S. B. Carpenter. *Reduction of rain forest understory vegetation by broadcast chemical spraying—sub-study 3*. 1966. (Unpubl. rep. on file at Institute of Pacific Islands Forestry, Honolulu, Hawaii.)

<sup>3</sup>Degener, Otto. *Plants of Hawaii National Park illustrative of plants and customs of the South Seas*. 312 p., illus. Ann Arbor: Edwards Brothers, Inc. 1930.

<sup>4</sup>Neal, Marie C. *In gardens of Hawaii*. Bernice P. Bishop Museum, Special Publication 50. 924 p., illus. Honolulu: Bishop Museum Press. 1965.

<sup>5</sup>Joe, Barbara. *Cultivated treefern of the genus cibotium*. Bailey 12, (4): 137-146. 1964.

<sup>6</sup>*Weather data for the Waiakea—Olaa reforestation area (1966-1969)*. (On file at Institute of Pacific Islands Forestry, Honolulu, Hawaii.)

<sup>7</sup>Ripperton, J. C. *The Hawaiian treefern as a commercial source of starch*. Hawaii Agr. Exp. Sta. Bull. 53. 16 p., illus. 1924.

<sup>8</sup>Nelson, R. E. and E. M. Hornibrook. *Commercial uses and volume of Hawaiian treefern*. U.S. Forest Serv., Pacific SW. Forest & Range Exp. Sta., Tech. Paper 73, 10 p., illus. 1962.

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